Multi-modal image fusion for small animal studies in in-line PET /3T MRI

Stéphanie Bricq, Hiliwi Leake Kidane, Alain Lalande, Hein Haas, Angela Camacho, Jean-Marc Vrigneaud, Paul-Michael Walker, Alexandra Oudot, Xavier Tizon, Bertrand Collin, et al.

Multi-modal image fusion for small animal studies in in-line PET /3T MRI

Stéphanie Bricq[1], Hiliwi Leake Kidane[1], Alain Lalande[1,2*], Hein Haas[3], Angela Camacho[4], Jean-Marc Vrigneaud[5], Paul-Michael Walker[1,2], Alexandra Oudot[5], Xavier Tizon[6], Bertrand Collin[5,8], Stéphane Roux[7], Mathieu Moreau[8], Jorge Zavala-Bojorquez[1], Franck Denat[8], François Brunotte[1,2,5]

[1]Laboratoire d'électronique, informatique et image (Le2I UMR CNRS 6306), Université de Bourgogne, Dijon, France
[2]CHU de Dijon, Dijon, France
[3]TriFoil Imaging France, Dijon, France
[4]MR Solutions Guildford, Surrey, United Kingdom
[5]Centre Georges-François Leclerc, Dijon, France
[6]Oncodesign Biotechnology, Dijon, France
[7]Institut UTINAM (UMR CNRS 6213) Equipe « NCM », Université de Franche-Comté, Besançon, France
[8]Institut de Chimie Moléculaire de l'Université de Bourgogne (ICMUB, UMR CNRS 6302), Dijon, France
[*]Corresponding author: alain.lalande@u-bourgogne.fr

Abstract – In the framework of small animal multi-modal imaging, the current progression of the IMAPPI project is illustrated by the design of an in-line PET/MRI prototype, coupled to a dedicated multi-resolution registration method allowing the robust fusion of data coming from both modalities. The first results show a good alignment of the data from tumor imaging at the level of the abdomen.

Index terms - Image Processing, Magnetic Resonance Imaging, Nuclear Imaging.

I. INTRODUCTION

Small animal Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) are becoming an integral part of preclinical studies for evaluating new pharmaceutical agents and exploring new biological functions. In the framework of the IMAPPI project (Integrated Magnetic resonance And Positron emission tomography in Preclinical Imaging - MRI and PET coupled in preclinical imaging), the main objectives are to develop complete protocols of preclinical imaging for an integrated PET-MRI system, including all the steps i.e. the management of the small animals (rats and mice), the development of new molecular probes, the image acquisition protocol, the matching of the data from PET and MRI (attenuation correction of PET data using MRI data and realignment of the data in time and space) and the automatic extraction of physiological parameters (design of complete and ergonomic software).
The prototype is a system with both a 3 T magnet (MR Solutions) and a PET scanner (BioPET, Bioscan) with a bed (Minerve®) that fit with both scanners without moving the animal or interrupting the anesthesia. The current steps are to design an in-line micro-PET integrated with 3T micro-MRI and to develop robust post-processing in order to match images. Additional post-processing is needed in order to tackle physiological movement such as breathing and bowel motion, because the acquisitions are not simultaneous.

II. MATERIALS AND METHODS

II.1. Assembling the prototype

Figure 1 summarizes the global workflow of the design of the in-line integrated PET/MRI prototype. It was decided to use a PET equipped with LYSO/LGSO crystals coupled to a network of avalanche photodiodes (APD), which are less sensitive to the magnetic field. The standalone PET from TriFoil Imaging has been modified to package the electronics in order to reduce the axial width as well as to increase the shielding. The PET ring is then docked in front of the 3T superconducting cryogen-free MR system from MR Solutions. The original preparation table of the MR has been removed and replaced with an elongated bed drive that is customized to host a mouse or rat holding cell from Minerve®.

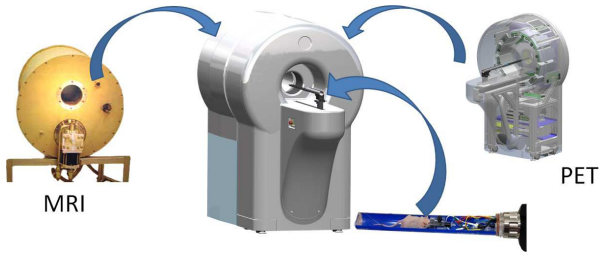

Figure 1: The design of the in-line prototype.

II.2. Automatized PET-MRI registration

The prototype will be mainly dedicated to oncologic studies at the level of the abdomen and to cardiovascular studies. So, matching the complementary information from the two modalities is mandatory, and this step needs additional post-processing. Indeed, as the acquisitions are not simultaneous, movement at the level of the thorax and/or abdomen must be taken into account. A two-stage registration approach has been proposed (Figure 2). Our work was inspired by the idea of Likar and Pernus [1] to follow a hierarchical approach for locally deformed images

and also considers the work of Lu and Chan [2] and Bernier *et al.* [3] to use principal component analysis (PCA) for computing the initial parameters for the global affine transformation.

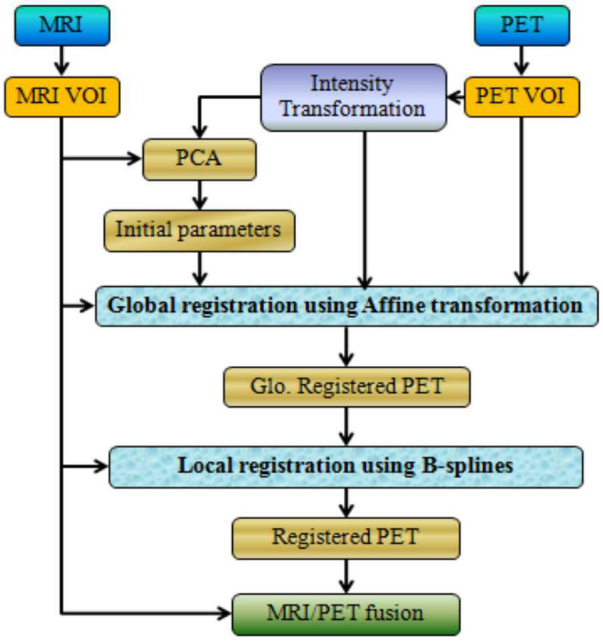

Figure 2: Flow diagram of the PET-MR registration

Firstly, a non-uniform intensity transformation is applied to the PET volume to increase the contribution of the low intensity (in order to get the global shape of the small animal). Then a global affine registration is applied, using PCA. Afterwards, the global transformation applied on the original PET is used as an input to the local registration. Normalized mutual information is considered as a metric function for the optimization. Finally, a local deformable registration (B-spline) is used taking the globally registered PET as input. A multi-resolution approach is used in global and local registrations.

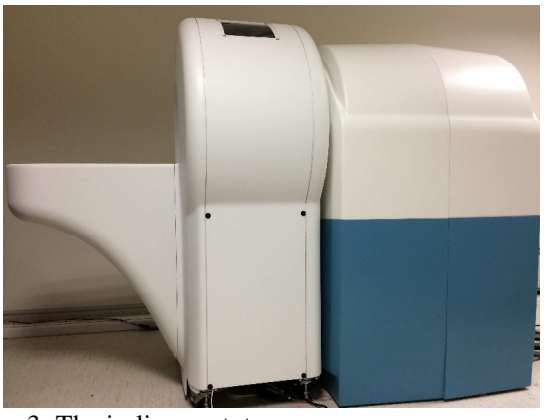

Figure 3: The in-line prototype.

III. RESULTS

Figure 3 shows the current version of the in-line prototype. Examples of automatized registration of FDG PET and MRI of mice are displayed in figure 4. These results indicate that the registered PET are visually well-aligned with the MRI slices.

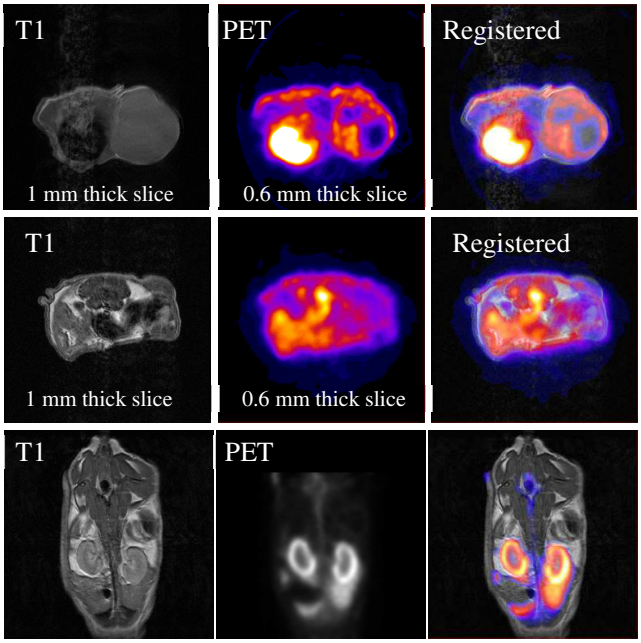

Figure 4: Examples of PET/MR data registration (with case of mouse having a tumor on the first line).

IV. DISCUSSION – CONCLUSION

In the framework of the IMAPPI project, a prototype of an in-line micro-PET integrated with 3T micro-MRI was developed for small animal studies. However, imaging being not strictly simultaneous in the in-line configuration of PET/MR imaging, it remains mandatory to properly realign PET and MR data. To this end, an automatized tool has been developed. The first results provided by our proposed method are encouraging, but further tests are needed in order to validate it.

ACKNOWLEDGMENTS

This work was supported by a French Government grant managed by the French National Research Agency (ANR) under the program “Investissements d’Avenir” (with reference ANR-10-EQPX-05-01/IMAPPI Equipex) and by the “Fondation de Coopération Scientifique PRES Bourgogne Franche Comté”.

REFERENCES

[1] B. Likar and F. Pernus. “A hierarchical approach to elastic registration based on mutual information”. *Image and Vision Computing*, 2001, Vol. 19, pp33-44.

[2] Z. Lu and W. Chen. Fast and Robust 3-D Image Registration Algorithm Based on Principal Component Analysis., *ICBBE* , 2007, pp. 872-875.

[3] M. Bernier, R. Lepage, L. Lecomte, L. Tremblay, L. Dor-Savard and M. Descoteaux. Free-Form B-spline Deformation Model for Groupwise Registration. *ISMRM*, 2011, pp. 3255.